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Research in Developing More Efficient Harvesting Machinery and Utilization of Crop Residues

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Abstract
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Research in Developing More Efficient Harvesting Machinery and Utilization of Crop Residues

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THE main objective of farming is to grow energy in the form of digestible nutrients. Although the farmer measures his corn production in bushels per acre and his hay production in tons per acre, this does not give him a true measure of his productivity.

Also, crops with different storage efficiencies* must be stored for a period of time, and they differ in digestibility. Table 1 gives harvesting and storage efficiencies of various crops, the digestibility of the crop, and the total efficiency of the farming operations of harvesting, storage, and animal utilization.

Another way of determining the productivity of cropping systems is to compare the pounds of beef produced per acre or the cow maintenance days per acre produced by each crop, as shown in Table 2. Figures are not given for soybean harvesting because soybeans are used as a protein supplement rather than as an energy source for cattle.

If all these data, calculations, and assumptions are correct, the digestible nutrients of the maintenance ration that must be consumed each day to maintain a cow (determined by combining data from Tables 1 and 2) should be the same, regardless of the crop or crops used (Table 3). The results in Table 3 agree for dried shelled corn and corn silage, and they agree reasonably well for hay.

By inference from Tables 1-3, the primary losses in harvest are from crop residue (stalks, leaves, shucks, tassles, and cobs), which are not collected but thrown away on purpose. Combines in the Soviet Union traditionally have been equipped with straw bunchers. Corn harvesting equipment with stalk collectors has been developed in the Soviet Union, Hungary, and Rumania during the past 10 years.

DOUBLING THE PRODUCTIVE CAPACITY OF THE FARMER

Farmers wishing to double their productivity and, thus, to improve their cash flow may do so by either doubling the number of acres farmed or by changing to a more efficient method of harvesting the crops now grown.

The cost of doubling the size of a 162 ha (400 acre) farm at $2964 per ha ($1200) an acre is approximately $480,000, plus cost of another set of tillage, planting, cultivating, and harvesting machinery at about $80,000, bringing the total to

TABLE 1. HARVESTING AND STORAGE EFFICIENCY OF VARIOUS CROPS.

Type of harvest	Harvesting and storage efficiency	Digestibility	Efficiency of harvesting, storage, and utilization
Dried shelled corn	41-46 percent	90 percent	37-41 percent
Corn silage	81-87 percent	70 percent	57-61 percent
Soybean grain	40-50 percent	—	—
Field cured alfalfa hay	74-83 percent	60 percent	44-50 percent

*The efficiency of grain harvest compared with grain on standing stalk ranges from 83-87 percent.

TABLE 2. BEEF PRODUCED AND COW MAINTENANCE DAYS PER ACRE.

Crop	Moisture	Available DDM* Kg/ha	Available DDM* (lb/acre)	Beef per acre (lbs) Kg/ha	Beef per acre (lbs) (lbs/acre)	Cow maintenance days per/ha	Cow maintenance days (per acre)
Dried shelled corn	20-25 percent	4906	(4,379)	812	(725)	1246	(505)
Corn silage	65 percent	12705	(11,340)	1757	(1,568)	2515	(1,018)
Field curred hay (no rain)	20 percent	7080	(6,320)	594	(530)	1156	(486)

*Digestible dry matter

TABLE 3. DIGESTIBLE NUTRIENTS IN THE MAINTENANCE RATION.

Crop	Available DDM* (lbs) Kg/ha	Total efficiency percent	Digestible nutrients Kg/ha	Digestible nutrients (lb/ac)	Cow maintenance days Kg/ha	Cow maintenance days (lb/ac)	Digestible nutrients consumed each day in a maintenance ration (lbs) Kg	Digestible nutrients consumed each day in a maintenance ration (lbs) (lb)
Dried shelled corn	4989	76	3753	(3,349)	1247	(505)	3.00	(6.63)
Corn silage	12710	59	7500	(6,694)	2515	(1,018)	2.98	(6.57)
Field cured hay	7083	47	3328	(2,970)	1156	(486)	2.77	(6.11)

*Digestible dry matter.
†$\frac{0.85 \times 0.90}{}$ =

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*Storage efficiency = $\frac{\text{weight of grain out of bin}}{\text{weight of grain into bin}}$

$560,000. The cost of changing the method of harvesting involves the purchase of a new harvesting machine for the 162 ha (400-acre) farm, which would cost about $40,000, and the purchase of 400 head of brood cows for utilizing the roughage at $300 per head, $120,000 total. This brings the total for changing the method of harvesting to $160,000—a savings of $400,000.

The following five systems have been used in a cooperative research program conducted by the Animal Science and Agricultural Engineering Departments of Iowa State University and by farmers in Iowa and Illinois. Analysis is on the__basis of a 7528 kg/ha (120 bu/acre) yeild of grain corn and 6,722 kg/ha (3 tons/acre) of dry plant parts.

WHOLE-PLANT SILAGE

Harvest the entire crop with a field harvester equipped with a row head. The whole-plant silage provides an excellent ration for dairy cows, but must be limited when fed to brood cows to prevent them from becoming fat. But limit-fed brood cows stand around bawling and are cold. These animals must be fed low-grade hay.

GRAIN AND SHUCKLAGE

Combine corn and collect shucklage (consisting of cobs and shucks) in trailing wagon. Approximately 2,241 kg/ha of dry matter (1 ton per acre) is collected (Ayres 1973). Feeding trials show that cattle consume approximately ½ of the shucklage 1,120 kg/ha (½ ton per acre). The animals utilize about 14 percent of the available DDM. The utilization could be improved to about 20 percent by processing the cobs in this system.

GRAIN AND STACKS OF PLANT PARTS

The combine collects the kernels of corn, and discharges the cobs, shucks, and stalks broken off by the corn head in a windrow behind the combine. After a period for drying, pick up the combine discharge and center two rows of stalks with a stack wagon (self-loading, self-unloading forage wagon) or with a giant round baler. Nearly all the husks and approximately 3/4 of the cobs are harvested along with the stalks. The theoretical percentage of cornstalks harvested with this plan depends on the size of the combine: 2 row, 100 percent; 4 row, 50 percent; and 6 row, 34 percent. These harvesting efficiencies are based on a 90 percent pickup efficiency of the cob and husk. Because the grain lost from the rack and shoe is lost, this ration must be supplemented with grain.

TABLE 4. CORN CROP RESIDUE AVAILABLE ON-FARM AND OFF-FARM USES.

	(Pounds per acre)	Kg/ha
Total corn crop residue produced	6000	6722
Prevention of wind and water erosion	2000	2241
Drying of high-moisture corn	250	280
Heating of farm house	250	280
Feeding to livestock	500	500
Total corn crop residue available for feeding cows or for off-farm use	3000	3361

EAR CORN SILAGE AND STOCKLAGE

Harvest ear corn silage with a forage harvester equipped with an ear-corn snapper head for feeding to fat cattle. Harvest stocklage consisting of stalk, leaves, tassel, silk and some shucks for placing in the silo with a second pass of the forage harvester equipped with a row-crop cut-off head for feeding to brood cows and pregnant heifers. This system harvests the ears hanging on the stalk, the stalks, and about 70 percent of the leaves, but the harvested products may not be in the best form for utilization for some farmers and livestock feeders. The corn must be fed on the farm or in the local community.

GRAIN AND PLANTLAGE HARVESTED WITH A TOTAL CORN HARVESTER

Harvest the entire crop with a total corn harvester or with a combine equipped with a grain head and pulling a forage chopper. High-moisture grain is elevated to the grain tank, and plantlage (consisting of stalk, leaves, cobs, tassles, silks, and some grain) is elevated into the forage tank or wagon. The grain may be dried and sold on the commercial market or elevated into high-moisture grain storage structures for local feeding, and the plantlage stored in silos. Research by the Animal Science Department of Iowa State University has shown that plantlage, when supplemented with mineral and protein blocks, is an excellent brood cow and pregnant heifer feed. A rule of thumb is that the moisture content of plantlage is twice the moisture content of the grain. This system harvests the entire crop of digestible nutrients and ends up with grain and a desirable feed that stores well in bunker silos.

ANALYSIS OF THE HARVESTING SEASON

Total corn harvesting should begin when the grain is at about 36 percent moisture content. Because the moisture contnet of the grain drops ½ percent each day, the number of days available for total corn harvesting (between 35 percent and 22 percent moisture content) is 26 days. This gets the harvest started early, maximizes the use of machinery, and produces storable plantlage.

COMPETITION FOR THE CROP RESIDUES

There are many uses for the crop residues besides feeding cattle or plowing under to improve the tilth of the soil. The competitive use and quantity needed of the corn crop residues on the farm is shown in Table 4.

The commercial competitive uses of corn crop residues are shown in Table 5.

Items 1, 2, and 3 in Table 5 can use all the crop residues and all the other organic residues from field and forest that can be harvested. The utilization for energy of all the crop residues available 3361 kg/ha (1½ tons/acre) for off-farm use could furnish more than 20 percent of the nation's energy needs.

TABLE 5. COMMERCIAL USES OF CROP RESIDUES.

1. Burning in electric generating steam boilers
2. Methane production
3. Methanol production
4. Wallboard
5. Paper
6. Furfural

TABLE 6. FUEL VALUE, SULFUR CONTENT, AND COST OF COAL AND CORNSTALKS.

	Average heating value		Sulfur Content				
	J/KgX10^6	(BTU/lb)	percent	\$/JX10^9	(\$/MBTU*)	Kg sulfur/ JX10^9	Lbs/ sulfur/ MBTU
Kansas coal	27.9	(12,000)	4.0	0.94	(1.00)	1.43	(3.33)
Wyoming coal	21.6	(9,300)	0.5	1.05	(1.11)	0.13	(0.54)
Iowa corn-stalks	18.1	(7,800)	0.06	0.61	(0.64)	0.018	(0.08)

*Includes price of coal at mine plus transportation to Ames, Iowa, and cost of harvesting cornstalks plus local transportation.

USE OF PLANTLAGE FOR FEEDING BROOD COWS

Research shows that 2727 kg (3 tons) of plantlage, when properly supplemented with minerals and protein, will feed a brood cow for 1 year. Grain, however, must be fed at calving time to promote a milk supply for the nursing calf.

Twelve million acres of Iowa corn could thus support an 8-million brood cow herd. With 90 percent calf drop, 7 million head of calves will be produced. This calf crop would fulfill Iowa's need for calves and yet leave approximately 3 million head for exporting to Texas, Kansas, and other western states. The other Corn Belt states also would have calves for exporting to other states or countries. This development depends, not on increasing the acreage of corn, but only on harvesting what is already grown.

Stiff competition to the brood cow for the corn residues will come from using cornstalks as a fuel in steam boilers.

Table 6 compares the fuel value and sulfur value (content and cost delivered to generating plant) of Kansas and Wyoming coal and cornstalks.

Table 6 shows that cornstalks are a premium fuel, which must be rationed and burned with high-sulfur coal to reduce the sulfur content of emissions to the EPA prescribed level.

The time will come when the prescription for farming will dictate the quantity of crop residues that must be left on the land on the basis of the slope of the land, the type of conservation tillage system, soil type, crop, etc. Trade-offs will be permitted in which a farmer planting corn on ridges layed out across the slope can remove all the above-ground residue, while another farmer using a chisel plow must leave 3362 kg/ha (1½ tons/acre) of residue in the field.

CONCLUSIONS

The energy problem being faced by America will require the farmer to remove surplus crop residues for feeding brood cows, heating farm houses, drying grain, and for off-farm energy generation, paper making, etc.

The first call for crop residue will be for protecting the soil from wind and water erosion. The farmer cannot do much about the slope of land and soil type, but he can employ conservation tillage systems to increase the quantity of crop residues that can be made available for off-field uses.

The development of machinery for harvesting the crop residues and conservation tillage equipment is needed for feeding the brood cow herds and for providing a portion of the nation's fuel supply.

Reference

1 Ayres, George E. 1973. An evaluation of machinery systems for harvesting the total corn plant. Unpublished Ph.D. thesis. ISU Library Microfilm Order No. 749101.